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ADVANCED MARINE TECHNOLOGY

Earl E. Hays, et al

Woods Hole Oceanographic Institution

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This is a progress report for the period 1 August 1973 - 31 January 1974 on the following projects in Advanced Marine Technology: (a) Submerged Navigation. (b) Hydraulic Impact Hammer. (c) Self Contained Ancillary Modular Platform. (d) Modular Acoustic System. (e) Wide Area Illumination.

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TECHNICAL PROGRESS REPORT

ADVANCED MARINE TECHNOLOGY

1 August 1973 - 31 January 1974

By

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May 15, 1974

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Approved for Distribution Earl E. Hays
Earl E. Hays, Chairman
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TABLE OF CONTENTS

	Page
Report Summary	I
Technical Reports	
(a) Submerged Navigation	1
(b) Hydraulic Impact Hammer	24
(c) Self Contained Ancillary Modular Platform	27
(d) Modular Acoustic System	37
(e) Wide Area Illumination	42

Report Summary

Contrary to the statement in the previous progress report (WHOI-73-92) we have decided to issue the final technical reports on Submerged Navigation, Hydraulic Impact Hammer, Deep Sea Rock Drill and the Self Contained Ancillary Modular Package (SCAMP) as separate reports. These are underway in various stages and will be issued as completed.

This six months has seen successful use of the navigation system in direct and surface bounce modes, testing of the "lock on" system of SCAMP to an ALVIN model and steady progress in the Modular Acoustic System.

Summaries of the reports included in this progress report are:

(a) Submerged Navigation

The direct and surface bounce navigation geometrics are discussed. Experimental results from a dive in the Tongue of the Ocean are given that show the direct path to be reliable to about four meters and the surface bounce path to about 30-50 meters. These numbers depend strongly upon the geometry of the relative beacons/submersible/ship positions. An error analysis of the system is given. In addition a solution for the survey of three reference beacons so as to reduce error is included. The use of systems of this type for mooring emplacement and tracking of instruments is discussed.

(b) Hydraulic Impact Hammer

The hammer has been tested from ALVIN in controlled conditions and works well, but events have conspired to prevent its use to collect samples in the real world. A hand is being added to the rock drill to make the system independent of the mechanical arm normally used on ALVIN.

(c) Self Contained Ancillary Modular Platform

SCAMP has been in the water and checked out. The "lock on" system was tested while clamped to an equivalent to ALVIN's skids. The "lock on", unlock, and emergency dump operations all worked properly. A twenty-four hour exposure to surface wave action while locked on caused no separation between SCAMP and mock ALVIN.

The "through window" optical control system has gone through its breadboard tests and some changes will be made in final packaging.

(d) A Deep Submersible Modular Acoustic System

The control/display system and the trainable mount are almost completed. Transmitter/battery assemblies have been fabricated and tested. The surface and submersible computers are being interfaced to other hardware and appropriate programs have been written for the system.

(e) Wide Area Illumination

This project started 1 December 1973. By the end of January a street light system (tethered to float above ALVIN) had been designed and is under construction.

Submerged Navigation

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Submerged Navigation

Introduction

One of the objectives of this development program has been to investigate a surface bounce signaling path for deep submergence navigation in adverse terrain. Adverse terrain, for the purposes of this report, is defined as terrain sufficiently steep and complex that due to topographical blanking a near bottom submersible is prevented from maintaining direct acoustic contact with near bottom moored navigation reference transponders. With any conventional long base line navigation system this results in the system becoming inoperative.

The conclusions of the investigation conducted are:

1. that there is a demonstrated need for a solution to near bottom topographical blanking of long base line navigation reference beacons for near bottom submersible operations, and

2. that the problem can be solved with surface bounce signaling, but

3. surface bounce navigation of a submersible is less accurate than conventional direct path position determination.

The main body of this report is presented in six sections as follows:

I. Normal and Surface Bounce Signaling

II. ALVIN Navigation Sea Trials

III. Discussion of Sea Trial Results

IV. Error Analysis for Ship and Submersible Operations

V. Three Beacon Survey with Error Estimates

VI. Results from other Navigation Systems at WHOI.

Section I presents a review of normal signal paths used by the ALVIN navigation system and describes the surface bounce signal paths.

Section II describes ALVIN sea trials conducted in the Tongue of the Ocean (TOTO) very early in 1974. A two transponder reference net was used. The first three hours of bottom time on ALVIN Dive 504 is elaborated upon. During this period 75% of the 134 position fixes obtained required using surface bounce signaling from either or both reference transponders.

Section III elaborates upon the results of ALVIN Dive 504. The problems of jitter in the acoustic signal for both direct path and surface bounce signaling is discussed in terms of its effect on the resolution of the navigation system.

Section IV presents an error analysis of the ALVIN navigation system. This section is based on the study and the mathematical work of James A. Metzler which was done in preparation for the Internal Wave Experiment (IWEX).

Section V describes a new computer program for the solution of the survey of three reference beacons. Several investigators at WHOI share a common concern for and have supported the studies that have resulted in program SWURV. Of particular interest is the section of the program that provides an error analysis of the survey conducted. The program can also be used before going to sea to design the optimum survey pattern for any given beacon geometry. Preliminary results obtained with this program have radically revised various approaches as how to survey stations should best be located. The effect of the location of survey stations is given for five surveys and is shown to be very significant.

Section VI comments on some of the results obtained at WHOI using modified ALVIN type navigation systems.

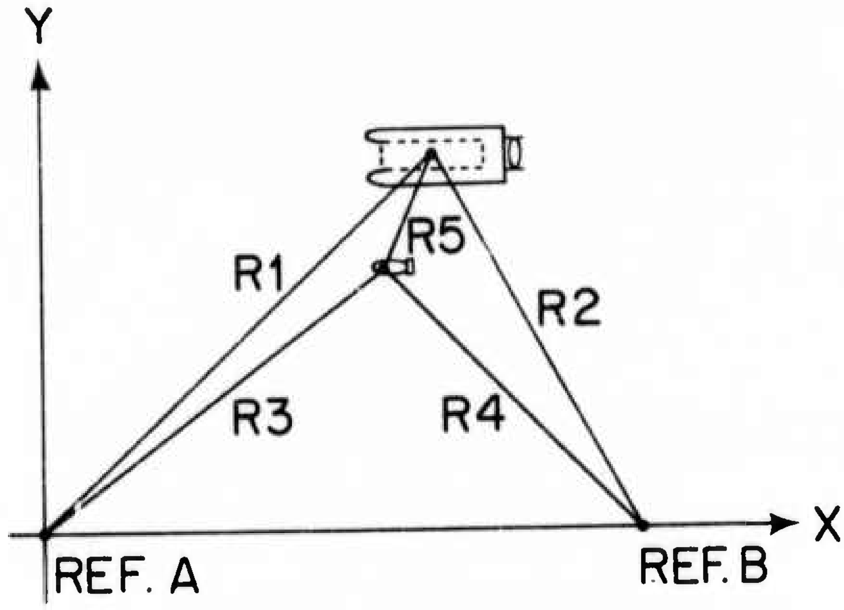
I. Normal and Surface Bounce Signaling

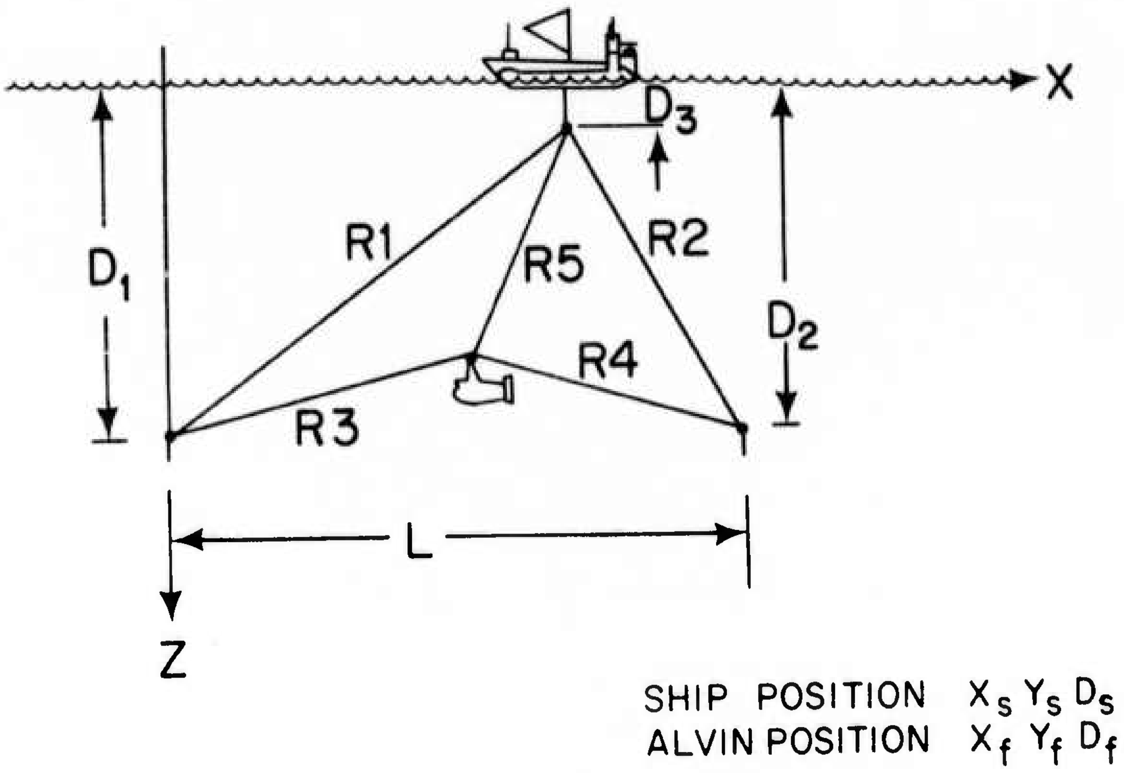
Normal Signal Paths

Figure 1 illustrates the normal acoustic signal paths utilized for the ALVIN navigation system. The ALVIN position is obtained in a two step process. The first step is to determine the slant ranges between the ship and two near bottom reference transponders, R1 and R2. These ranges, plus a prior knowledge of which side of the transponder base line the ship is operating, permits calculating the position of the ship relative to the two transponders. Both the ship and ALVIN carry precision clocks which are synchronized during the ALVIN predive checkouts. These clocks control the alternating ship (Step I) and submersible (Step II) interrogations of the near bottom reference transponders. At the beginning of Step II, the surface clock starts time interval counters and the ALVIN clock causes ALVIN to transmit a transponder interrogation. This signal travels to and interrogate the two reference transponders (R3 and R4). This signal also travels to the ship (R5), is received and stops a time interval counter. The transponder replies travel to the ship (R1 and R2), are received and stop additional time interval counters.

Let t1, t2, t3, etc. represent the one way acoustic travel time along signal paths R1, R2, R3, etc. respectively. Disregarding fixed system time delays, during Step I, the shipboard receiver channel A counter will read 2(t1) and the B counter reads 2(t2).

During the Step II ALVIN cycle the "A" counter reads "t3+t1" and the "B" counter reads "t4+t1". The channel D counter reads "t5". One can obtain "t3" and "t4" by subtracting "t1" and "t2" determined during Step I from the "A" and "B" counter readings obtained during Step II. The three travel times (t3, t4, and t5) are converted to slant ranges (R3, R4 and R5)by a calculation that uses a





GEOMETRY FOR SHIP AND SUBMERSIBLE NAVIGATION PROBLEM.

Figure 1.

stored sound velocity profile. Given R3, R4, R5 and having calculated (Step I) the X and Y of the ship, the position of the submersible is calculated by the solution of the intersection of three spheres. Depending on the geometry, this calculation can result in two solutions. To solve this redundance the operator inputs the approximate depth of the submersible. The calculator program selects the solution that gives a depth nearest to the approximate depth.

To compensate for ship motion between Step I and Step II, it is customary to average Step I readings taken before and after the Step II readings to obtain an ALVIN position determination.

Surface Bounce Signal Path

Figure 2 illustrates the R3 plus R1 signal path when the direct path from ALVIN to transponder A is observed by local topography. Reference 1 describes the mathematics to solve the ALVIN position equations when one or more signal paths are via surface bounce. It was shown that by changing the sign of depth of the transponder(s) interrogated via surface bounce that the normal position equations give the proper solution. Changes are also required to calculate the slant ranges of the signal paths from the measured travel times. This involves additional steps to evaluate the effective sound velocities from the submersible to the surface (for R3a) and from the surface to a transponder (for R3b).

II. ALVIN Navigation Sea Trials

On 28 January 1974 two transponders were set in TOTO approximately midway between Andros and New Providence Islands. A ship survey of these transponders was conducted that night with the following results:

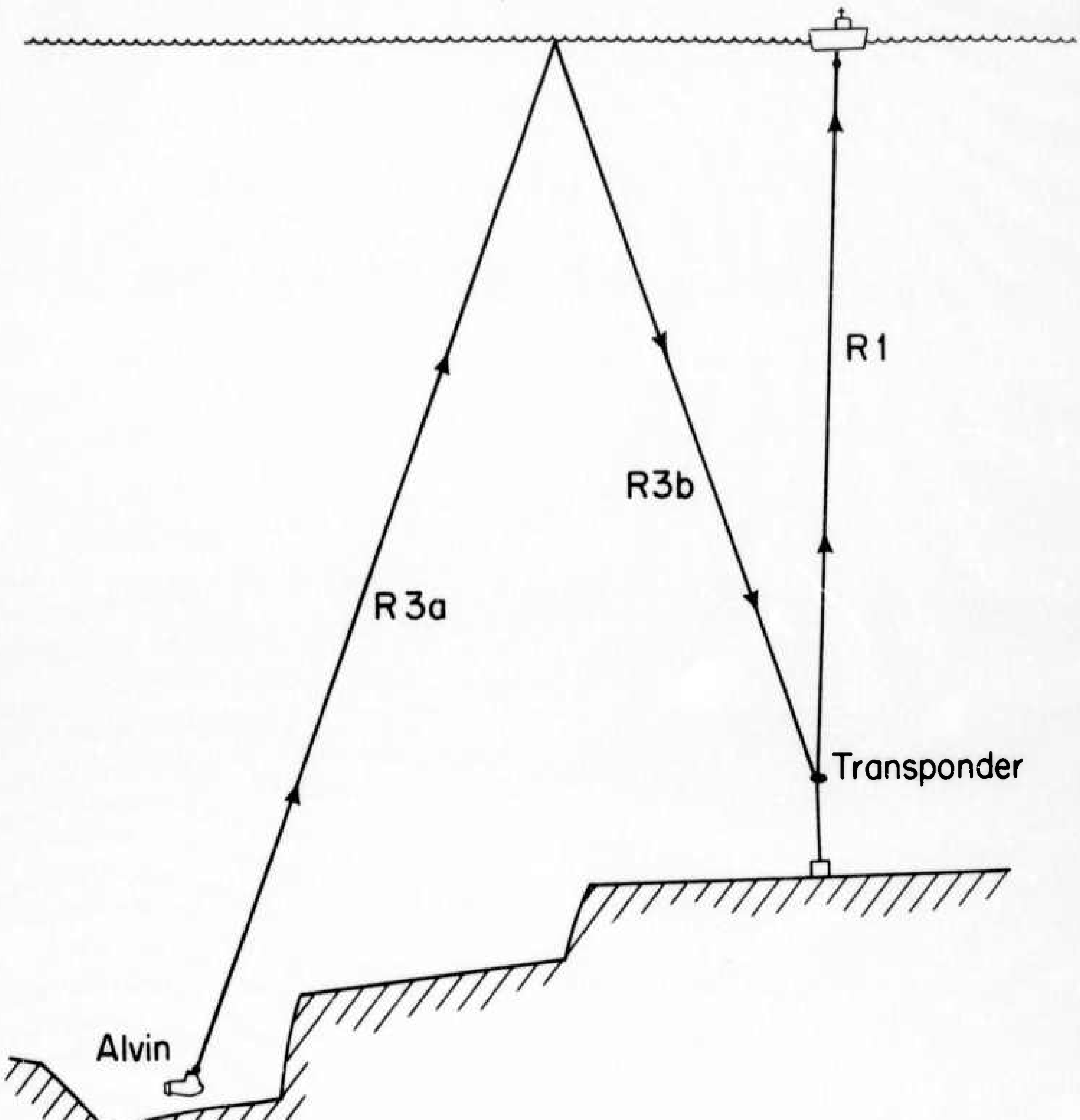
Depth of Transponder A:	2142 meters (7,028 feet)
Depth of Transponder B:	2168 meters (7,113 feet)
Horizontal Separation, A-B:	2859 meters (1.54 NM)
Rotation, A to B:	192° true North

The first half of ALVIN Dive 504 is reported as typical of the results of the cruise.

ALVIN DIVE #504

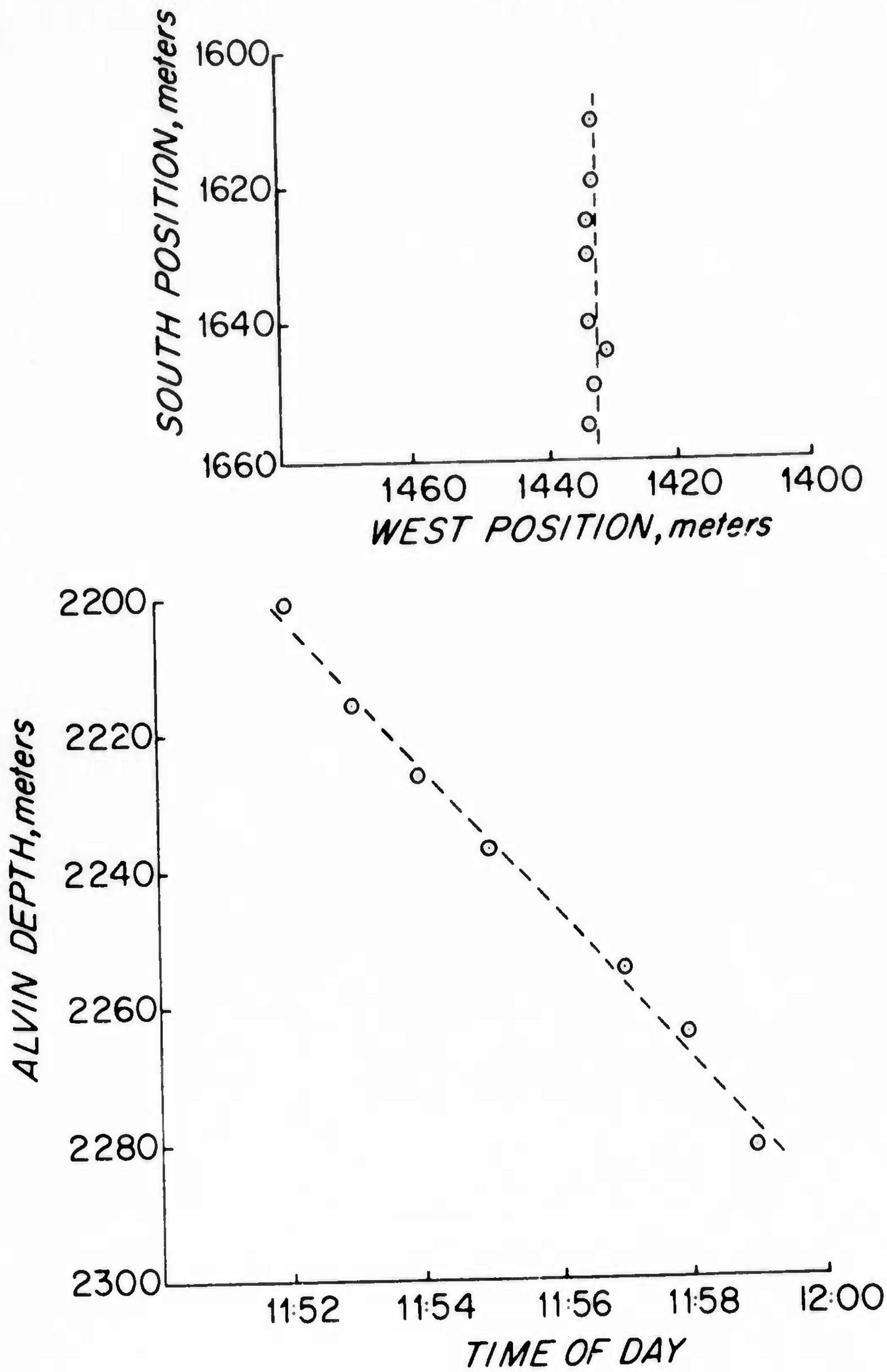
ALVIN was launched west of the base line 2100 meters from transponder A and 1600 meters from transponder B. She made a normal descent to 1700 meters when a course correction to the bottom target point was given from LULU. This mid-descent position correction was executed by ALVIN and she approached the bottom within 50 meters of the target point.

Figure 3 is a plot of ALVIN Dive 504 positions obtained during the last eight minutes of the free-fall, approximately steady state, descent. This plot is typical of the $\pm$2-4 meter position resolution obtainable with good, direct path, signal conditions. During this part of the descent ALVIN was approaching the bottom at 0.35 knots and was



ALVIN SURFACE BOUNCE SIGNAL PATHS

Figure 2.



ALVIN POSITIONS DURING FINAL PHASE OF DIVE 504 DESCENT

Figure 3.

being set north at 0.18 knots.

At 12:02 when ALVIN was approximately 30 meters above the bottom, the transponder A travel time increased from 3.3 seconds to 5.3 seconds. It will be developed later in this report that this jump in the measured travel times was caused by a transition from direct to surface bounce signaling. At this time ALVIN was 2150 meters from transponder A. The transponder was moored 300 feet above the bottom but because the transponder was on the uphill side from ALVIN, the transponder was 188 meters (617 feet) higher than ALVIN. On a typical bottom this difference in altitude should have been more than sufficient to provide direct path signaling. The loss of direct path signaling was not predicted from the bathymetry charts of the area. Upon visual inspection the bottom was found to consist of a series of terraced steps and canyons. Typical vertical relief was 100 feet. When ALVIN was at the base of one of the steps the direct signal path was lost. When ALVIN rose to the top of a step the direct signal path was usually regained.

Table I presents the calculated positions of ALVIN for seven successive fixes. Two of the fixes were taken with direct signaling from ALVIN to transponder A. The other five were calculated for surface bounce signaling from ALVIN to transponder A. An inspection of the table shows that there is a very good correlation between the positions calculated by the two methods. Table I is typical of the correlations between direct and surface bounce signaling calculations. These correlations have convinced the writer that jumps in the transponder A acoustic signaling times are in fact caused by a transition to and from surface bounce signaling.

Figure 4 is a plot of the channel A time interval counter readings vs time of day. The counter readings are those of the ALVIN cycle (Step II) of the two step position determining measurements. The acoustic travel times shown represent the time it took an interrogation to travel from ALVIN to transponder A plus the time it took transponder A's reply to travel to LULU. Between 1140 and 12:01 pm ALVIN was making her descent to the bottom. When ALVIN was approximately 30 meters from the bottom the direct signal path to transponder A was lost. For the next 83 minutes transponder A was blanked except for two data points at 12:38 and 12:40 pm.

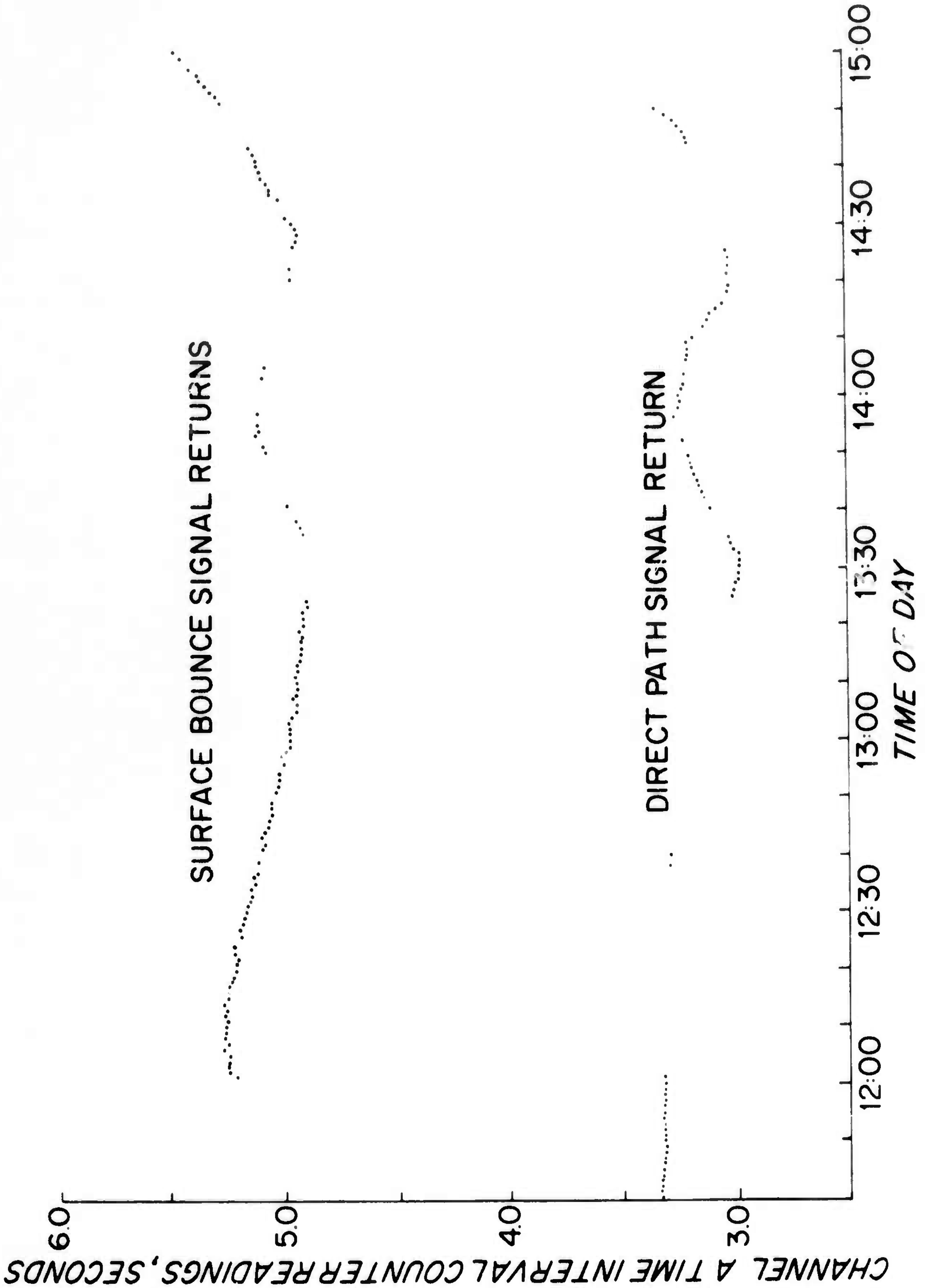
The surface bounce signal is also present when the direct path signals are being received. The reason that this does not show on the figure is that the digital receiver stops when it receives a reply to an interrogation and is not enabled until the next interrogation is sent, thus blanking a surface bounce reception if it is preceded by a direct path signal.

An inspection of Figure 4 indicates that the transitions from direct path to surface bounce signaling is very sharp. Without the surface bounce programs the position of ALVIN would not have been known for a major portion of the dive.

TABLE I

ALVIN Dive #504

Time	Counter A Millisecond	Signal Path	ALVIN Position South	West	Depth
12:36 pm	5142	Bounce A	1709m	1478m	2341m
12:37	5126	Bounce A	1672m	1448m	2349m
12:38	(3299)	DIRECT	1693m	1498m	2334m
12:39	5120	Bounce A	1686m	1488m	2339m
12:40	(3281)	DIRECT	1679m	1499m	2338m
12:41	5102	Bounce A	1627m	1457m	2360m
12:42	5102	Bounce A	1658m	1486m	2347m



CHANNEL A TIME INTERVAL READINGS
VS. TIME OF DAY. ALVIN DIVE 504

Figure 4.

III. Discussion of Sea Trial Results

The resolution of an acoustic navigation system is usually limited by the jitter in the time interval measurements made to calculate the various slant ranges. The position of ALVIN is calculated using slant ranges R3, R4, R5 as defined in Figure 1. The signal paths used to obtain R3 and R4 are the more complex and the most difficult to measure accurately. The jitter of the time interval "t3", used to obtain R3, will be elaborated upon. The comments also apply to "t4" which is used to obtain R4.

The time interval "t3" is the one way acoustic travel time between the submersible and transponder A. When "t3" is multiplied by the effective sound velocity between the submersible and the transponder A, one obtains R3.

The time interval "t3", disregarding fixed system delays, is determined from:

$$t3_{15} = T3_{15} - \frac{(T1_{o}+T1_{30})}{4}$$

where T3 is the measured time interval from the beginning of the Step II submersible interrogation of transponder A to the stopping of the digital receiver on the ship, and

where T1 is the measured time interval from the beginning of the Step I ship interrogation of transponder A to the stopping of the digital receiver on the ship, and

where the subscripts indicate the time in seconds that each measurement is started.

The major causes of jitter in time interval "t3" are caused by:

a. Variations in the turnaround time of transponder A, typically less than 0.5 milliseconds.

b. Variations in the stopping time of the shipboard digital receiver, typically less than 0.5 milliseconds.

c. Non-linear motion of the ship between the two Step I interrogations of transponder A.

d. Resolution of shipboard digital receiver which counts at 1 millisecond intervals.

e. For the surface bounce signal path added jitter is introduced due to variations in the mirror quality of the sea surface.

Figure 5 presents typical measured values for the time interval "t3" obtained during ALVIN dive #504. During the twenty minutes of direct path signaling illustrated, "t3" had a jitter of ± 1.5 milliseconds. This causes a range uncertainty of approximately ± 2 meters.

It is judged that the most significant cause of the observed jitter is the motion of the ship. As one would expect when "t3" is obtained using a surface bounce signal path the observed jitter is larger. Disregarding the three obviously late returns, the spread of the observed surface bounce signaling jitter was 7 milliseconds. This corresponds to a range uncertainty of approximately 10 meters.

The effect of a 10 meter slant range error in the calculated position of ALVIN depends on the geometry. Favorable geometry would give an error multiplication factor of two which would result in a 20 meter error in determining the position of ALVIN. Because the surface bounce signal paths are steep in the vertical plane the error multiplication factor increases. Assuming an error multiplication factor of 5, a 7 millisecond timing error will produce a 50 meter position error. An inspection of the realtime plot of ALVIN obtained from dive #504 gives a position jitter during surface bounce operation of ±30-50 meters when operating at a distance greater than 1000 meters from the base line. While this position jitter is much worse than the ±2-4 meter jitter obtainable with direct path signaling it is obviously much better than no position at all.

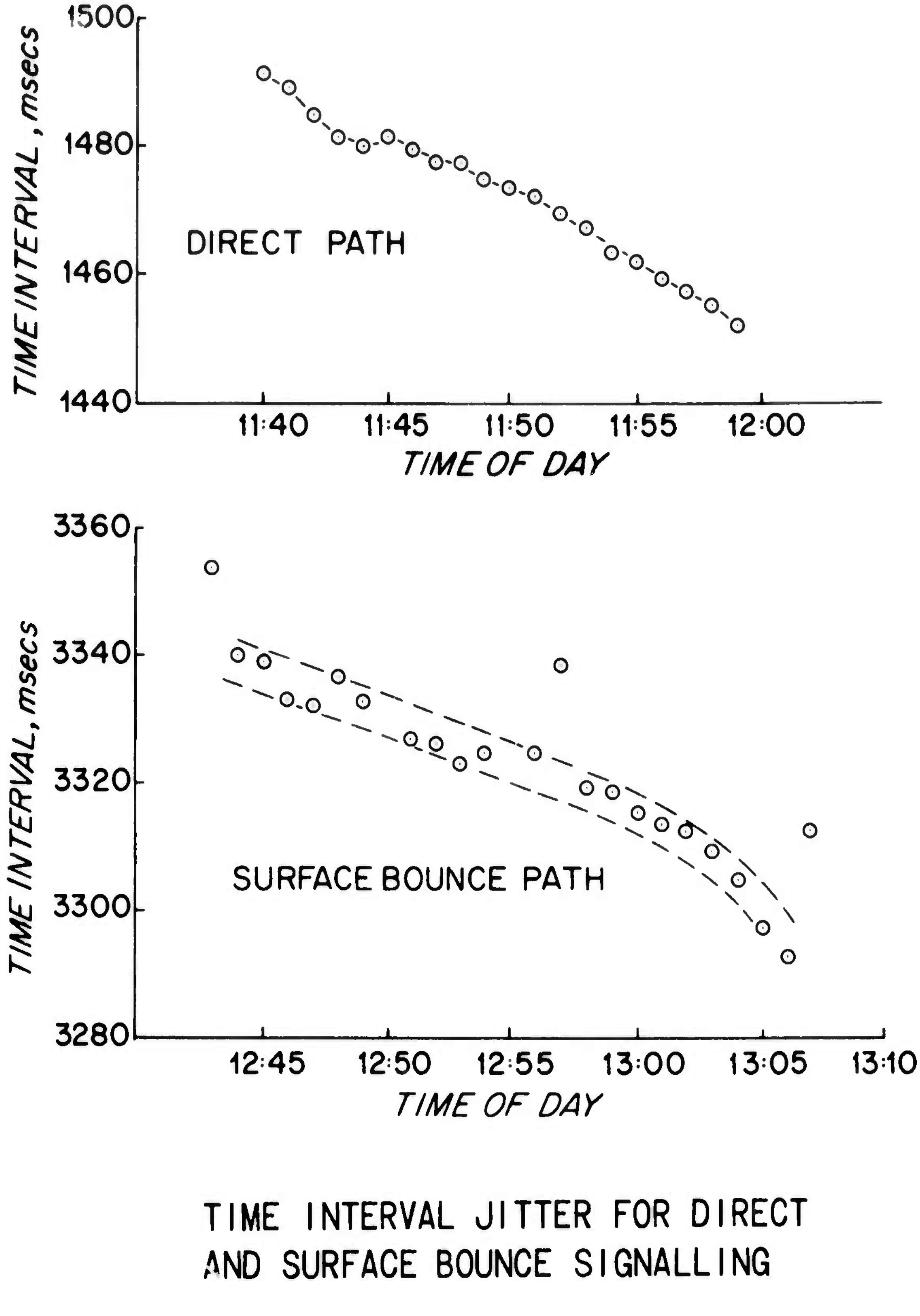
The majority of travel time jitter observed during surface bounce measurement is attributed to the non-perfect mirror effect of the sea surface. This effect will be sea state and geometry dependent. ALVIN dive #504 was conducted under sea state 2-2½ conditions. An improvement in surface bounce signaling is predicted for lower sea states and vice versa for higher sea states. It should be noted that surface ship tended small submersibles seldom operate in sea states greater than 3 due to limited launch and recovery systems.

During the latter part of dive #504 ALVIN approached to within 250 meters of the reference two transponder base line. Under these conditions the geometry became very unfavorable for both the direct path positioning and the surface bounce positioning. Relatively few data points were obtained, but the indications were that the direct path position jitter became a still useful ±10 meters while the surface bounce position jitter became an unusable ±300 meters. The jitter is seen predominantly in a direction perpendicular to the transponder base line as would be expected, i.e. Y_f becomes ill conditioned. Both theory and the above observations indicate that if operations are conducted near a two transponder base line that significant penalties in accuracy must be accepted. This is particularly true for operation in a surface bounce mode. For surface bounce signaling a suggested rule of thumb is that submersible operations should not be planned nearer than ½ the water depth of a two transponder base line. This rule of thumb assumes that the two transponders will be separated by 1-1½ water depths. If a longer base line is used then the submersible operations should be planned further from the base line.

IV. Error Analysis for Ship and Submersible Operations

Reference 1 developed the surface origin equations for ship and submersible location using two near bottom transponders as references. Figure 1 provides definitions for the symbols used in the error analysis that is discussed below. The x-position of the ship can be found using:

$$\text{(1)} \qquad Xs = \frac{(R1)^2 - (R2)^2 + L^2 + (D2 - Ds)^2 - (D1 - Ds)^2}{2L}$$



TIME INTERVAL JITTER FOR DIRECT AND SURFACE BOUNCE SIGNALLING

Figure 5.

Let δXs equal the error in the x-position of the ship, Xs. Similarly let $\delta R1$, $\delta R2$, δL, etc. represent the errors in the other parameters. Replacing (Xs) in the above equation with $(Xs + \delta Xs)$, and similarly adding error terms for the other variables, yields:

$$(2) \qquad Xs + \delta Xs = [(R1 + \delta R1)^2 - (R2 + \delta R2)^2 + (L + \delta L)^2 + (D2 + \delta D2 - Ds - \delta Ds)^2 - (D1 + \delta D1 - Ds - \delta D2)^2]/2(L + \delta L)$$

In order to see the significant terms when this equation is expanded, it is convenient to disregard second order terms such as $(\delta R1)^2$ etc., as well as the δL in the term $(L + \delta L)$. Ds is neglected as it has a very small absolute value. The last simplifying assumption is that D1 is approximately equal to D2 and that (D1 - D2) can be neglected. With these assumptions, the error in the x-position of the ship can be expressed as:

$$(3) \qquad \delta Xs \approx \frac{-(\delta L)\ [(R1)^2-(R2)^2+L^2]}{2L^2} + \frac{R1(\delta R1)}{L} - \frac{R2(\delta R2)}{L} + (\delta L) + \frac{D2\ (\delta D2 - \delta Ds)}{L} + \frac{D1\ (\delta Ds - \delta D1)}{L}.$$

To minimize δXs, the term (R1 + R2) should be minimized. For any given Ys, the term (R1 + R2) is minimized midway between the two transponders. Under these conditions δXs is dominated by the term δL. The survey of the transponder net established δL and should be carefully conducted.

The y-position of the ship is found from one of the two following equations:

$$(4) \qquad \text{for } R1 \leq R2: \quad Ys = [(R1)^2 - (Xs)^2 - (D1 - Ds)^2]^{\frac{1}{2}}$$

$$(5) \qquad \text{for } R1 > R2: \quad Ys = [(R2)^2 - (L - Xs)^2 - (D2 - Ds)^2]^{\frac{1}{2}}$$

performing an error expansion on equation (4) and applying the simplifying assumptions, the error analysis provided:

$$(6) \qquad \delta Ys \approx \frac{1}{2} \cdot \frac{e}{Ys} - \frac{1}{8} \cdot \frac{e^2}{(Ys)^3}$$

where $e = 2[R1\ (\delta R1) - Xs\ (\delta Xs) - D1\ (\delta D1 - \delta Ds)]$

To minimize δYs, the value of Ys should be large. In operational terms this means that ship operations should not be conducted near the base line of a two transponder net because excessive errors in Ys are likely to occur. The "e" term is minimized at Xs = 0

The error analysis of equation (5) is the same as equation (6) except that:

$$(7) \quad e = 2\,[R2\ (\delta R2) - (L-Xs)\ (\delta X+\delta L) + D2\ (\delta Ds - \delta D2)]$$

This term is minimized at Xs = L. The y-position error of the ship, δYs, is again decreased by increasing Ys.

The error analysis of the equations to find the error depth of the submersible, δZf, gave the following:

$$(8) \quad \delta Zf \approx \frac{(R5)\ \delta R5 + (Zf-Ds)\ \delta Ds}{Zf - Ds} + A$$

$$\text{where } A = \frac{(Xf-Xs)\ \delta Xs + (Xs-Xf)\ \delta Xf + (Yf-Ys)\ \delta Ys + (Ys-Yf)\ \delta Yf}{Zf-Ds}$$

The error in δZf can be minimized by keeping the ship directly over the submersible. This results in $(Xf-Xs) \approx 0$, $(Yf-Ys) \approx 0$, and the "A" term becomes insignificant.

The x-position error of the submersible, δXf, is given as follows:

$$(9) \quad \delta Xf \approx \frac{(R3)\cdot\delta R3}{L} - \frac{(R4)\cdot\delta R4}{L} + \delta L + B$$

$$\text{where } B = \frac{(D2-Zf)\,\delta D2 + (Zf-D1)\,\delta D1}{L}$$

For a submersible operating at or near the depths of the reference transponders the term "B" becomes insignificant. Under these conditions the submersible x-position error is dominated by the ability to accurately measure the slant ranges, R3 and R4, plus an accurate knowledge of the transponder base line as established during the survey of the net. In a fashion similar to the x-position of the ship, the x-position error of the submersible is minimized when operating midway between the two transponders, i.e. (R3 + R4) should be minimized.

The y-position of the submersible, Yf, is found from one of the two following equations:

$$(10) \quad \text{for } R3 \le R4: \quad Yf = [(R3)^2 - (Xf)^2 - (D1-Zf)^2]^{\frac{1}{2}}$$

$$(11) \quad \text{for } R3 > R4: \quad Yf = [(R4)^2 - (L-Xf)^2 - (D2-Zf)^2]^{\frac{1}{2}}$$

The y-position error of the submersible, δYs, for both cases is:

$$(12) \quad \delta Ys \approx \frac{e}{2Yf} - \frac{e^2}{8(Yf)^3}$$

where for $R3 \leq R4$: $e = 2[(R3)\delta R3 - (Xf)\delta Xf] + C$

where $C = 2[(Zf-D1)\delta D1 + (D1-Zf)\delta Zf]$

and for $R3 > R4$: $e = 2[(R4)\delta R4 + (Xf-L)\delta L + (L-Xf)\delta Zf] + D$

where $D = 2[(Zf-D2)\delta D2 + (D2-Zf)\delta Zf]$

When the submersible is operating at or near the depths of the reference transponders the terms "C" and "D" can be neglected. The y-position errors of the submersible, δYs, are dominated by the ability to accurately measure the R3 or R4 slant ranges, the value and error of Xf, plus when R4 is used, the accuracy of the survey of the transponder net. The y-position errors of the submersible, δYf, are minimized by operating far from the base line, i.e. Yf should be large and are further minimized when operating perpendicular to one of the two reference transponders.

In order to develop a picture of how the operating errors might vary as a function of position within the transponder net a computer run was made using the error equations developed for the ship. The following conditions were assumed:

Parameter			Type of Error	Assumed Error		
L	=	6000 meter	Survey	L	=	3 meters
D1	=	5100	"	D1	=	1
D2	=	5050	"	D2	=	1
Ds	=	30	Operating	Ds	=	1
R1	=	as required	"	R1	=	3
R2	=	as required	"	R2	=	3

The errors were assumed to combine in the <u>most unfavorable</u> way, i.e. all errors are assumed to add. The Xs errors were relatively insensitive to changes in position, lying roughly between 9 and 11 meters over a major part of the area investigated. The Ys errors were more sensitive to position and became large on and near the base line. Figure 6 presents the vector sum of the Xs and Ys errors for various ship positions. It should be noted that the assumed errors are relatively large and that further, that it was assumed that none of the errors cancelled, as is more likely the case. The results of this is that a well conducted operation should be able to half the worst case errors presented.

Beacon A (X = 0) — Beacon B (X = 6000)

X Position, Meters

Y Position, Meters	-400	0	400	800	1200	1600	2000	2400	2800	3200	3600	4000	4400	4800	5200	5600	6000	6400
0	245.	225.	244.	262.	278.	294.	309.	324.	338.	350.	344.	318.	309.	290.	270.	248.	224.	249.
400	69.	59.	69.	78.	87.	96.	106.	115.	124.	133.	128.	117.	106.	94.	83.	71.	59.	71.
800	37.	31.	37.	42.	47.	53.	58.	63.	69.	74.	71.	65.	56.	51.	45.	38.	31.	38.
1200	25.	21.	25.	29.	32.	36.	40.	43.	47.	51.	49.	44.	40.	35.	30.	26.	21.	26.
1600	19.	16.	19.	22.	24.	26.	29.	32.	35.	38.	37.	34.	30.	27.	23.	20.	16.	20.
2000	16.	13.	16.	18.	20.	22.	25.	27.	29.	32.	30.	27.	25.	22.	19.	16.	13.	16.
2400	13.	11.	13.	15.	17.	19.	21.	23.	25.	27.	25.	23.	21.	18.	16.	14.	11.	14.
2800	12.	10.	11.	13.	15.	16.	18.	20.	22.	23.	22.	20.	18.	16.	14.	12.	10.	12.
3200	10.	9.	10.	12.	13.	15.	16.	18.	19.	21.	20.	18.	16.	14.	12.	11.	9.	11.
3600	9.	8.	9.	11.	12.	13.	15.	16.	17.	19.	18.	16.	15.	13.	11.	10.	8.	10.
4000	9.	7.	9.	10.	11.	12.	14.	15.	16.	17.	17.	15.	13.	12.	10.	9.	7.	9.
4400	8.	7.	8.	9.	10.	11.	13.	14.	15.	16.	15.	14.	12.	11.	10.	8.	7.	8.
4800	8.	6.	8.	9.	10.	11.	12.	13.	14.	15.	14.	13.	12.	10.	9.	8.	6.	8.

Ship Position Errors, Meters, VS. X-Y Net Positions

Figure 6

V. Three Beacon Survey with Error Estimates (W. K. Smith)

Program SWURV is meant to be used in conjunction with other acoustic navigation programs. It calculates the depths and relative positions of a three-beacon array. Using travel time observations from a transducer near the surface to each of the beacons, taken from at least six different locations, SWURV modifies the initial estimated beacon positions until it finds the positions which best fit the observed data.

Before running SWURV, the travel time data on the input magnetic tape should be listed so the user can select records which appear to contain accurate data. This listing can be done by Program WHIP. SWURV requires a minimum of six sets of travel times (i.e., survey points); the maximum number is 100. Ideally the survey points should be selected from at least 12 distinct locations.

In addition to travel times, the user must input the sound velocity profile and ray-bending coefficients found by Program SETUP. These are needed to convert the travel times to distances, or slant ranges, between the transducer and each of the three beacons. The user must also supply estimates of the beacon positions. The other required parameter is the depth of the transducer.

The geometry of the survey program can be described as follows: A transducer at a known depth, ZS, measures slant ranges to three beacons located at $(0, 0, Z_1)$, $(X_2, 0, Z_2)$, and (X_3, Y_3, Z_3). The slant ranges are measured at nr survey points located at a depth ZS with X, Y coordinates (SX_1, SY_1), (SX_2, SY_2),...(SX_{nr}, SY_{nr}). Both the survey point coordinates and the beacon coordinates are unknown and must be estimated from the measured slant ranges. The slant range $SR_{i,j}$ from survey point i to beacon j is a function of the unknown survey point and beacon coordinates:

$$SR_{i,j} = [(SX_i-X_j)^2 + (SY_i-Y_j)^2 + (ZS-Z_j)^2]^{\frac{1}{2}}$$

where $X_1 = Y_1 = Y_2 = 0$.

The measured slant ranges at survey point i, $S_{i,1}, S_{i,2}, S_{i,3}$ are not identically equal to the true slant ranges since there are errors in determining travel times to the beacons and average sound velocity. The measured slant ranges are then:

$$S_{i,j} = SR_{i,j} + \varepsilon_{i,j} \; ; \quad i = 1,2,\ldots,nr \; ; \quad j = 1,2,3$$

where $\varepsilon_{i,j}$ is an error term associated with making the slant range measurement.

This survey problem can be thought of as a particular application of the design and analysis of nonlinear experiments as outlined in Box and Lucas (1959) and Draper and Smith (1966). If we assume that the $\varepsilon_{i,j}$'s are independent identically distributed normal random variables, then the maximum likelihood estimates of the beacon and sur-

vey point coordinates are the values that minimize the sum of squared errors between the measured slant ranges and the calculated slant ranges:

$$SS = \sum_{i=1}^{nr} \cdot \sum_{j=i}^{3} (S_{i,j} - SR_{i,j})^2$$

Program SWURV consists of two sections: the first determines the beacon and survey point coordinates that minimize SS, and the second part determines the approximate error covariance matrix of the beacon position estimates.

While the minimization procedure is taking place, the program outputs the current sum of squared errors and the latest estimates of the beacon positions after every iteration. This permits the user to ascertain that the procedure is not going astray.

When the procedure is completed, the final beacon position estimates are output, with the results of the error analysis. These include the correlation matrix for beacon positions, and the standard error and error magnification term for each of the six unknown beacon coordinates.

The standard error in estimating a beacon parameter, denoted by σ_i is composed of two independent terms,

$$\sigma_i = (\sigma_s)(M_i)$$

where σ_s is the standard error of the slant ranges and depends only on the accuracy of the slant range measurement. M_i depends on the number and positions of the survey points. We have defined a measure of the efficiency of the survey, the survey error, C, which is the sum of the squares of the error magnification terms:

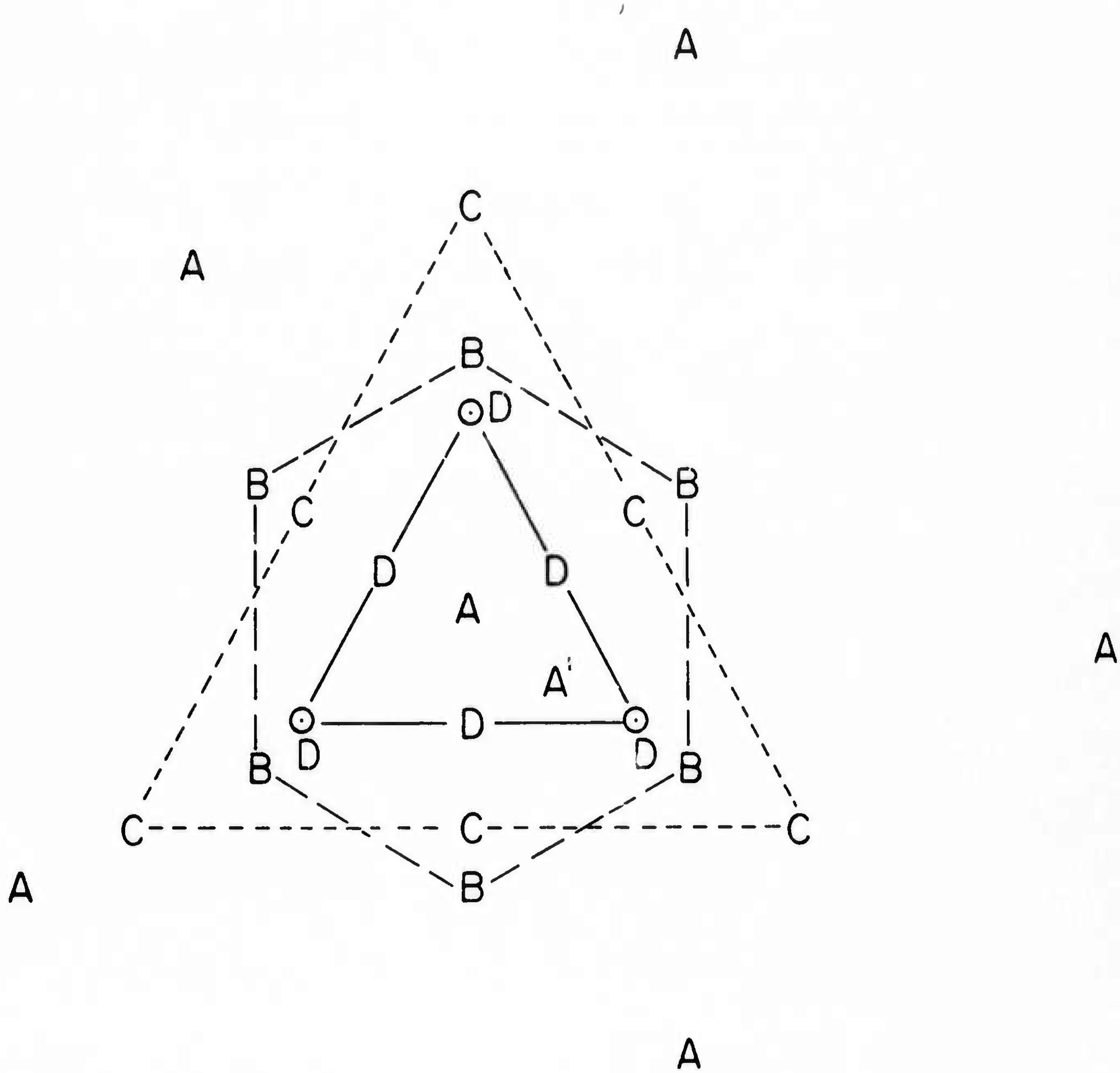
$$C = \sum_{i=1}^{6} (M_i)^2$$

The positions of the survey points relative to the beacons is important in determining the size of the errors in the estimates of the beacon coordinates. Of course, both the positions of the beacons and the survey points are unknown; however, in practice one can obtain approximate positions by estimated positions obtained when the reference beacons were launched or preliminary base line crossing survey runs.

In Figure 7 and Table II we give the results for a series of surveys labeled A, A', B, C, and D, each consisting of six survey points. Figure 7 gives the positions of the survey points and the beacons, and Table II gives the individual error magnification terms and the sum of the squares of the error magnification term, C, for each of the surveys.

The beacons in this example form an equilateral triangle 1,000 meters on a side and the depth of each beacon is 1,000 meters.

These theoretical calculations should be used only as a guide in designing good survey patterns. The theoretical model used to calculate the error magnification terms does not allow for the limited range of the sonar signal. Thus in many situations the optimal survey points A, are impractical.



BEACON POSITIONS -⊙- AND SURVEY POINTS FOR SURVEY A, A', B, C, AND D. SURVEY A AND A' ARE IDENTICAL EXCEPT FOR THE SURVEY POINT IN THE CENTER OF THE ARRAY

Figure 7.

TABLE II

Error Magnification Terms and Survey Error for the Survey Points in Figure 7

Survey	Error Magnification Terms, M_i						Survey Error
	X_2	X_3	Y_3	Z_1	Z_2	Z_3	$C = (M_i)^2$
A	1.35	1.74	1.20	1.15	1.11	1.09	10.05
A'*	1.37	1.74	1.26	1.34	.89	1.40	11.07
B	23.81	13.73	18.83	4.01	5.30	4.39	1173.58
C	1.94	2.41	1.61	.98	.98	.98	15.01
D	4.24	6.04	3.59	1.00	1.00	1.00	70.34

*Survey A' is the same as A except that the survey point in the center of the array has been moved to A'.

VI. Results from Other Navigation Systems at WHOI

Two modified copies of the ALVIN navigation system have been constructed at WHOI. The Physical Oceanography Department system has been used to support an Internal Wave Experiment (IWEX) The Geology and Geophysics Department system has been used to do preliminary work to support the French-American Mid-Ocean Undersea Study (FAMOUS).

IWEX

The R/V KNORR sailed from Woods Hole on 13 October 1973 to initiate the sea-going phase of IWEX. The navigation system was used to determine the locations of the mooring anchors of a three-legged mooring (trimoor). The operation had to be conducted in real-time with a maximum of accuracy. The anchors had to be very accurately lowered along a pre-calculated glide path to prevent overstressing the other legs. Secondly, the experiments placed on the mooring had to be correctly oriented to each other. The geometry of the transponder net used and final calculated positions of the anchors is given in Figure 8. Accurate placement of the anchors required both a precision navigation system and high quality seamanship.

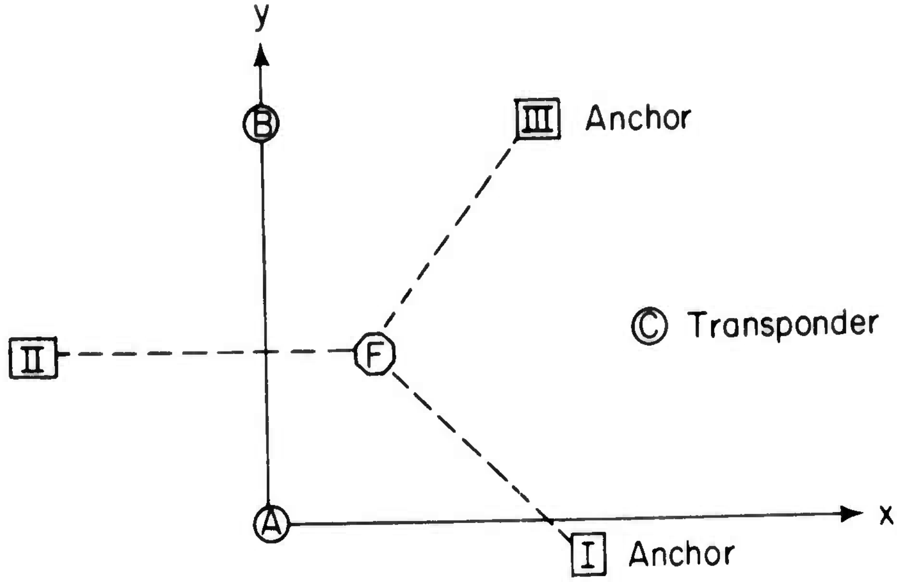
The water depth was 5,242 meters and each anchor was to be 5,950 meters from the other anchors. After each anchor was placed, the target point(s) for the remaining anchor(s) was recalculated to offset misplacement of the anchors already lowered. The first anchor was placed within 5 meters of the target point and the remaining anchors were placed within 18 meters of the target points. Considering the size and complexity of the mooring plus such factors as ship handling, weather, people interfaces, these results are impressive. Based on the error analysis and operational experience, the uncertainty of the anchor positions was estimated to be 10-15 meters. After the mooring was in place the depth of the apex float was measured and found to be within a few meters of the predicted depth.

FAMOUS

The Geology and Geophysics Department navigation system has been used to track ship lowered instruments and sonobuoys in the Mid-Atlantic Ridge in preparation for project FAMOUS.

During the data reduction several jumps in the lowered instrument (fish) tracks were observed. An inspection of the raw data showed transistions from direct to surface bounce signaling similar to those seen when tracking ALVIN. Several programming routines were considered to automatically call appropriate surface bounce subroutines. The simple final solution was to calculate the four possible direct and surface bounce positions and instruct the computer to select the fish position closest to the ship.

Based on tracking of the ship lowered instruments in the FAMOUS operating area, it is predicted that the surface bounce mode of positioning ALVIN will be needed to complement the normal navigation of ALVIN in the Mid-Atlantic Ridge operations scheduled for the summer of 1974.



FINAL POSITIONS RELATIVE TO
A B BASELINE IN METERS

		X	Y	Z
BEACON	A	0	0	5243
"	B	0	5486.4	5242
"	C	4938.7	2792.6	5243
ANCHOR	I	3401.4	-235.0	—
"	II	-1764.7	2728.3	—
"	III	3403.5	5712.0	—
APEX FLOAT		1672.4	2704.8	590

IWEX BEACON AND ANCHOR FINAL POSITIONS

Figure 8.

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Hydraulic Impact Hammer

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Ocean Engineering Department

Hydraulic Impact Hammer

Testing

The impact hammer was tested on ALVIN while LULU was tied to the dock. The submersible was lowered on the launch cradle and the impact hammer was tested with the submersible just below the surface of the water. A test stand holding a large granite block was mounted on the cradle. Impacts were made several times on the block resulting in rock fracturing in each instance.

Testing at Sea

A cruise was initiated in the Gulf of Maine during the summer of 1973 but problems with the submersible's hydraulic system cancelled the cruise before any submerged tests could be made with the submersible.

In December 1973, a second attempt was made to use the impact hammer in the Tongue of the Ocean but problems with the submersible's weight dropper and cancellation of the cruise due to problems with the submersible terminated the sea-going test program.

Modifications

In its initial design configuration, the impact hammer had to be used in conjunction with a mechanical arm so that samples broken off by the hammer could be picked up and placed in the science tray. To remedy this problem a hand is being constructed for the hammer system (Figure 1). When completed the hand will be able to pick up the hammer, use it, place it back on the tray, and pick up the sample.

This new modification will also give the submersible a second arm capability. The new arm is three to four times stronger than the present arm and weighs one-half as much.

Other modifications will be made on the hammer system when it returns from its southern diving program. These include strengthening the frame and mounting bracket so that the hammer system can be mounted directly on the submersible. It is still important to the completion of this task that adequate sea trials are conducted to fully test this system.

Figure 1.

Self Contained Ancillary Modular Platform

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Self Contained Ancillary Modular Platform

Abstract

The SCAMP platform was developed to provide a device that would enhance the load carrying ability of the ALVIN submersible. It provides the vehicle with auxiliary power to support various scientific apparatus. Using suction pod devices, the platform is capable of anchoring itself to the bottom.

Construction Milestones:

I. Frame

The frame assembly has been completed and the first in-water tests initiated. Figure 1 is an overall view of the device being prepared for its preliminary wet test. The gross air weight of the completed device is 4100 lbs. The water weight is a negative 50 lbs. with provisions available for a minimum of 17 syntactic blocks 6"x12"x24", for a total of 17 cubic feet of additional syntactic foam. In keeping with the original design goal of always retaining a 50 lb. negative buoyancy to assure the SCAMP will fall away from the submersible when released, the additional block of flotation provides a 544 lb. payload. The original design goal was 400 lbs. Figure 2 illustrates the completed frame undergoing water weight and preliminary operational tests.

In the event additional buoyancy is required, it is proposed that one-half cylindrical sections of syntactic foam can be fabricated to fit around the top and bottom of the tubular battery compartments on the SCAMP. A total of 18 pieces can be accomodated. The total additional buoyancy that can be obtained is 224 lbs., less 4 lbs. for mounting hardware. The total positive payload buoyancy now becomes 764 lbs.

All systems were tested completely submerged, to assure the surface test box had control of all the system circuits. Rail lock pumps, automatic pressure control of the rail lock system, emergency dump valve, battery traverse, and the three suction pod anchors operated in a satisfactory manner.

On completion of the preliminary tests, the platform was removed from the water and mated with a dummy ALVIN submersible frame. The rail lock clamps were actuated, securing the two assemblies into a single unit. The assembly was returned to the water as illustrated in Figure 3. The SCAMP and the simulated ALVIN remained submerged for a 24 hour period to assure the two devices would not separate due to local surface wave action. Throughout the test, the frame remained rigidly attached to the lift bridle and crane, which increased the wave action stress on the rail lock hose clamp assemblies.

At no time were there any indications of separation between the two assemblies. On completion of the 24 hour period, the rail locks were released using the normal pump down mode. The SCAMP fell away from the frame within a 37 to 45 second period of time. A retainer bridle restricted the fall to a two foot drop, preventing the inadvertent loss of the platform.

The test was repeated several times to assure proper operation of both the rail lock pump-up mode, as well as pump down, or release mode. The frame and SCAMP were remated and the emergency dump valve actuated. Despite indications that a sea water leak has developed in the nose cone housing the emergency valve and associated circuits, the dump system released the SCAMP satisfactorily. The test was repeated several times to assure proper operation.

On removing the frame and SCAMP from the water, it was found that the port nose cone had been 50% flooded with sea water. Further investigation revealed the tygon tubing connecting the delrin control manifold, Figure 4, that directs and controls the sea water flow to the rail lock tube clamps, had been cut by an over tightened hose clamp. During the rail clamp pump upmode, the positive pressure sea water pump had been forcing sea water directly into the nose cone control center, displacing the compensation oil used to fill the cavity. As all compartments are joined through common oil-filled lines, the excess oil was vented overboard through the normal vent relief valve located at the top of each battery compartment.

Damage consisted of corroded spade lugs and terminal boards located at the front of Figure 4. All defective components have been replaced. The pressure switch located at the base and far right of the manifold was replaced as a precautionary measure as it has open micro switches and had been exposed to sea water. The rail lock emergency dump valve, located at the base of the manifold and to the left of the pressure switch was not damaged as it is a totally encapsulated and potted assembly.

To prevent a reoccurrence of this failure mode, all tygon tubing used to connect the rail locks as well as the sea water pump and manifold have been replaced with a more rugged synthetic neoprene tubing. SCAMP has been refurbished, batteries charged, and is ready to start on the bottom shallow water suction pod tests as soon as the weather becomes satisfactory for diving.

II. SCAMP/Submersible Interface Optical Control System

The initial electronic circuit board for the pulsed light control system has been undergoing tests in the laboratory. The prototype circuit provides for ten control functions or switch closures, with the capability of being expanded at a later date.

In its basic form, the switch closures are coded into a serial BCD code which is used to control the escitation voltage of a xenon flash

tube. The receiver consists of a silicon photo cell which drives a two-stage narrow band amplifier and a bit sync detector. Decoding of the received pulse determines which power relay is actuated to operate the selected circuit.

The following tests were performed on the prototype circuit. Figure 5 illustrates a typical bench set-up used during the initial testing. The xenon transmitter tube is located at the right, the simulated ALVIN window is mounted between the silicon photo cell received head, at the left on the picture. The oscilloscope was used to measure the threshold trigger level of the receiver during the evaluation tests.

The prototype circuit was evaluated using the following parameters as a guide:

A. Determine the current drain of system when operating under various conditions of high and low voltage, transmitting, receiving and during the quiescent state.

B. Determine the lowest voltage the system will operate at without misfire or other malfunction.

C. Determine the maximum range of operation in air, varying the following parameters:

   a. External ambient light conditions.
   b. Low voltage effects.
   c. Effect of transmitter and pick up head misalignment.
   d. Effect of plastic window.

D. Can circuit be fooled by random pulses of light from sources other than the transmitter; for example, flood lamps, camera strobes, chopped light due to submarine flood lamp or sunlight passing through rotating propellers?

E. Will on-line voltage spikes cause the system to inadvertently trigger? The transmitter will be exposed to voltage spikes on the submersible power source due to high current relays on the propulsion and variable ballast pump motors. The receiver will be exposed to similar conditions but of a much smaller magnitude.

F. Can the circuit be fooled into a major state of misfire or relay drop-out that could result in its release from the submersible (rail lock release, emergency release relay)?

G. Check system operation at temperature extremes of 32°F and 125°F. Both ambient temperature extremes are possible during normal operation.

H. Check effect of simulated particles suspended in water; use of Kodak filter to reduce light hitting pick-up head.

On completion of the electronic test phase, the following items were determined to be necessary modifications to be included in the final design.

A. Modify the system to assure there are no function dropouts when the power is turned off, then placed in an on-position at a later date.

B. Automatic gain control to be included in the received to compensate for xenon transmitter tube aging, or possible diminishing voltage from the power pack.

C. Include a "ready-state" light to prevent the operator from pushing a new series of operations before the last command has been completed.

D. Increase the speed of operation, to assure the final version of 100 mode operation can be handled with a minimum time lag.

E. Critical circuits such as emergency or normal rail lock functions must be designed to assure inadvertent operation.

The new circuit is in the design stage, and construction should start within several weeks. It is anticipated that the pressure housing design and fabrication will start as soon as the physical size of the new electronic package has been determined.

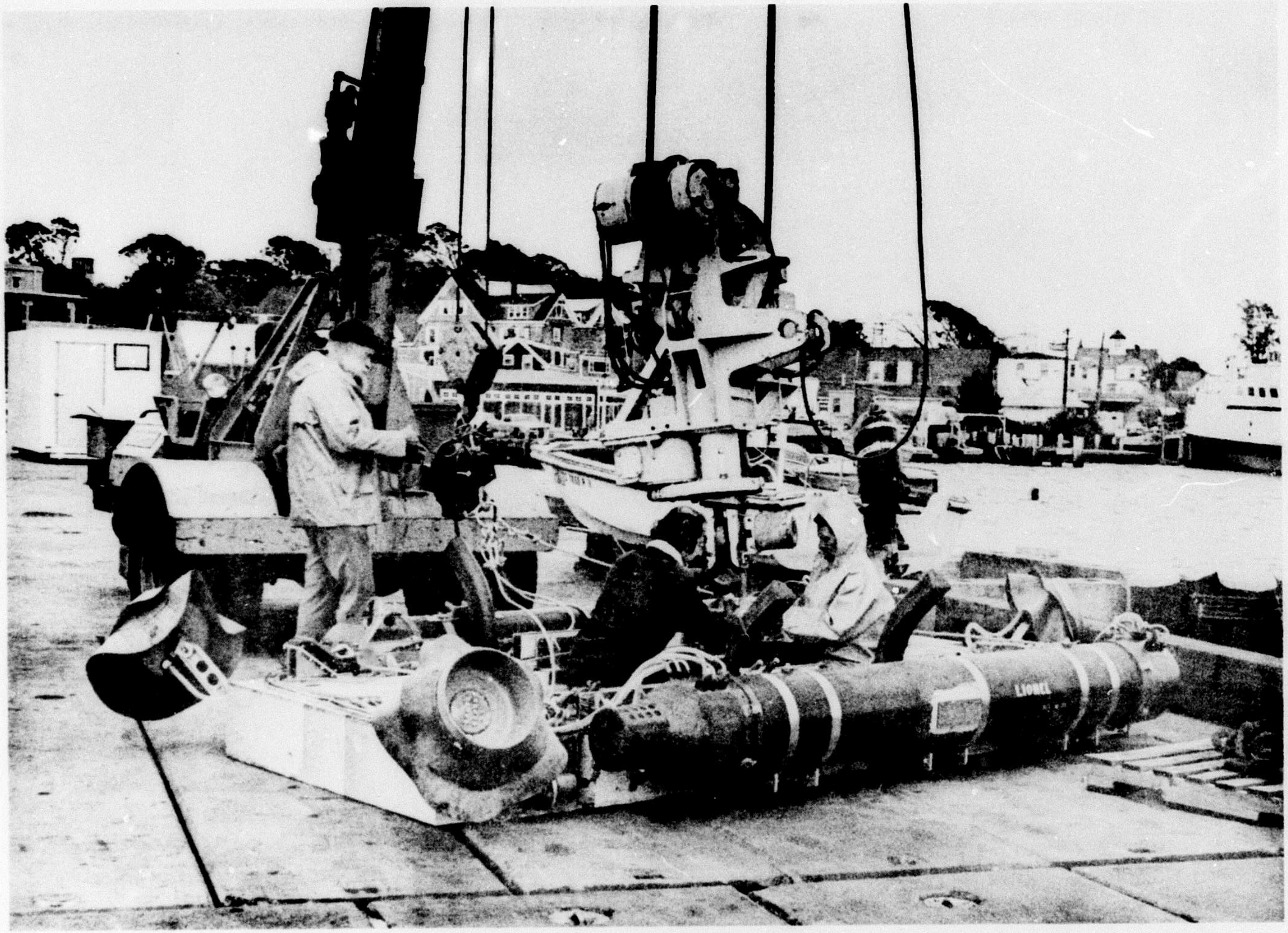

Figure 1. Final Preparations for the First In-water Operational Tests

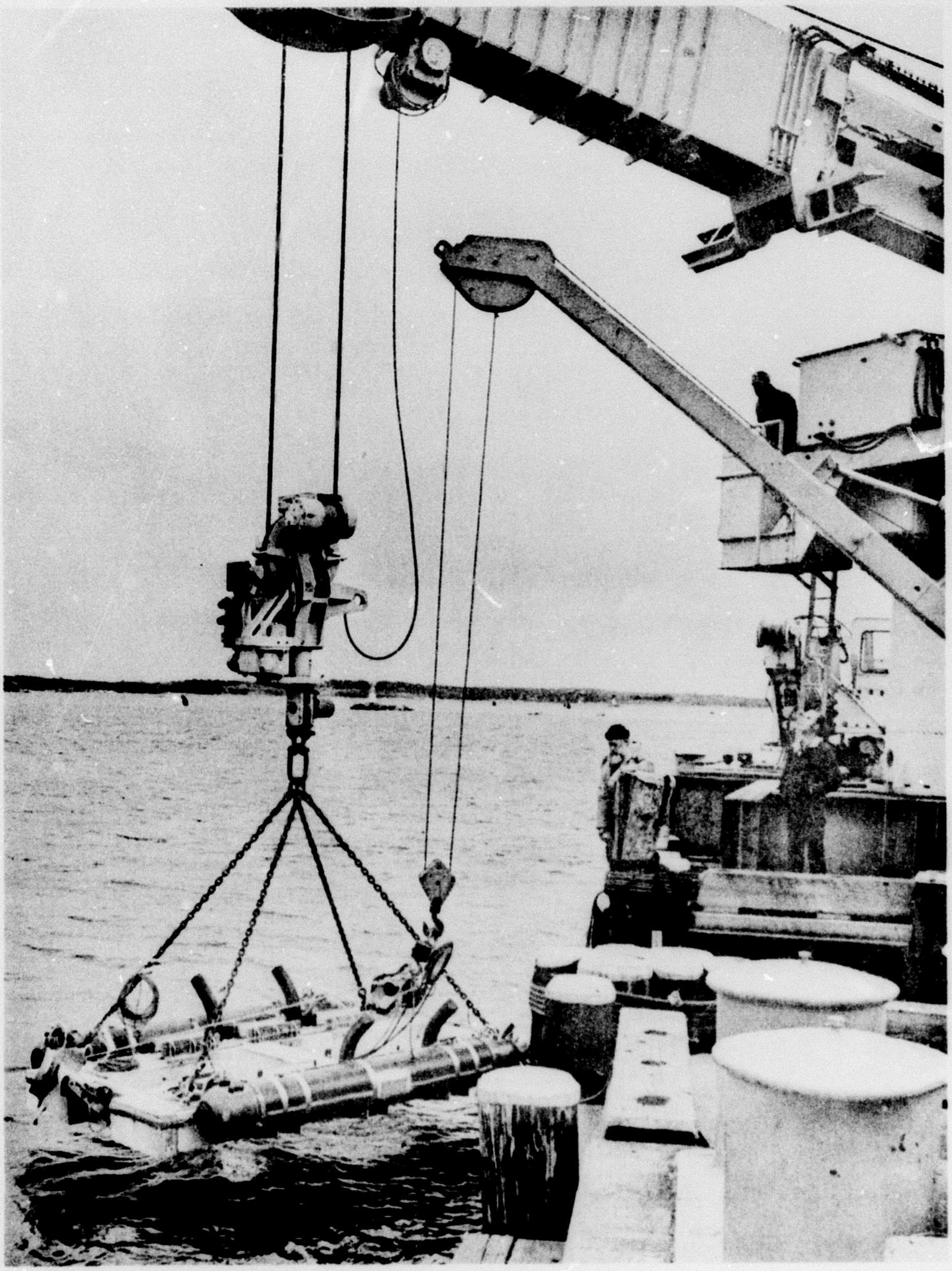

Figure 2. Initiation of the Dock-side Weight and Balance Test

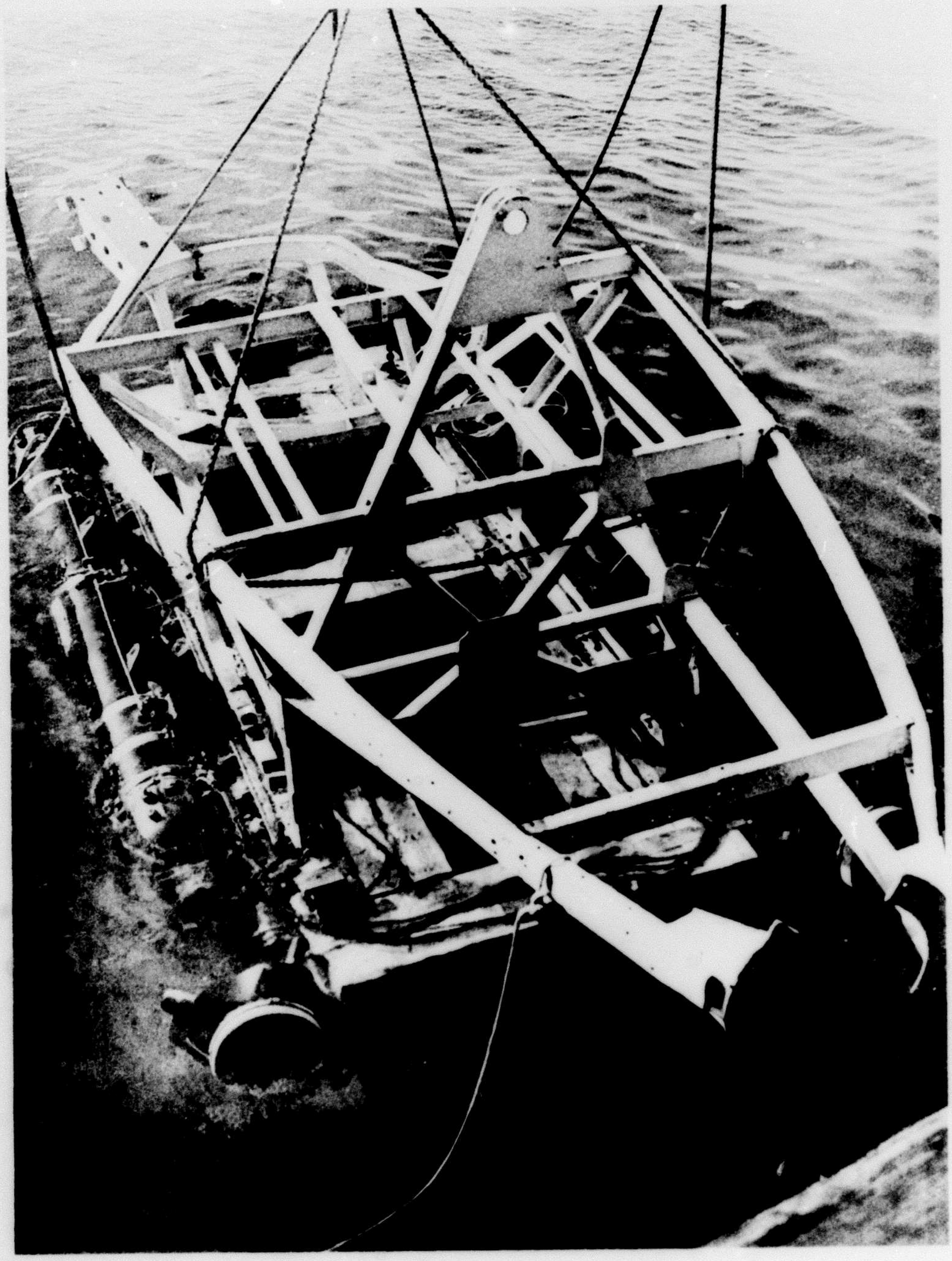

Figure 3. Skid Clamp Actuation and Emergency Release Test Using a Simulated ALVIN Frame

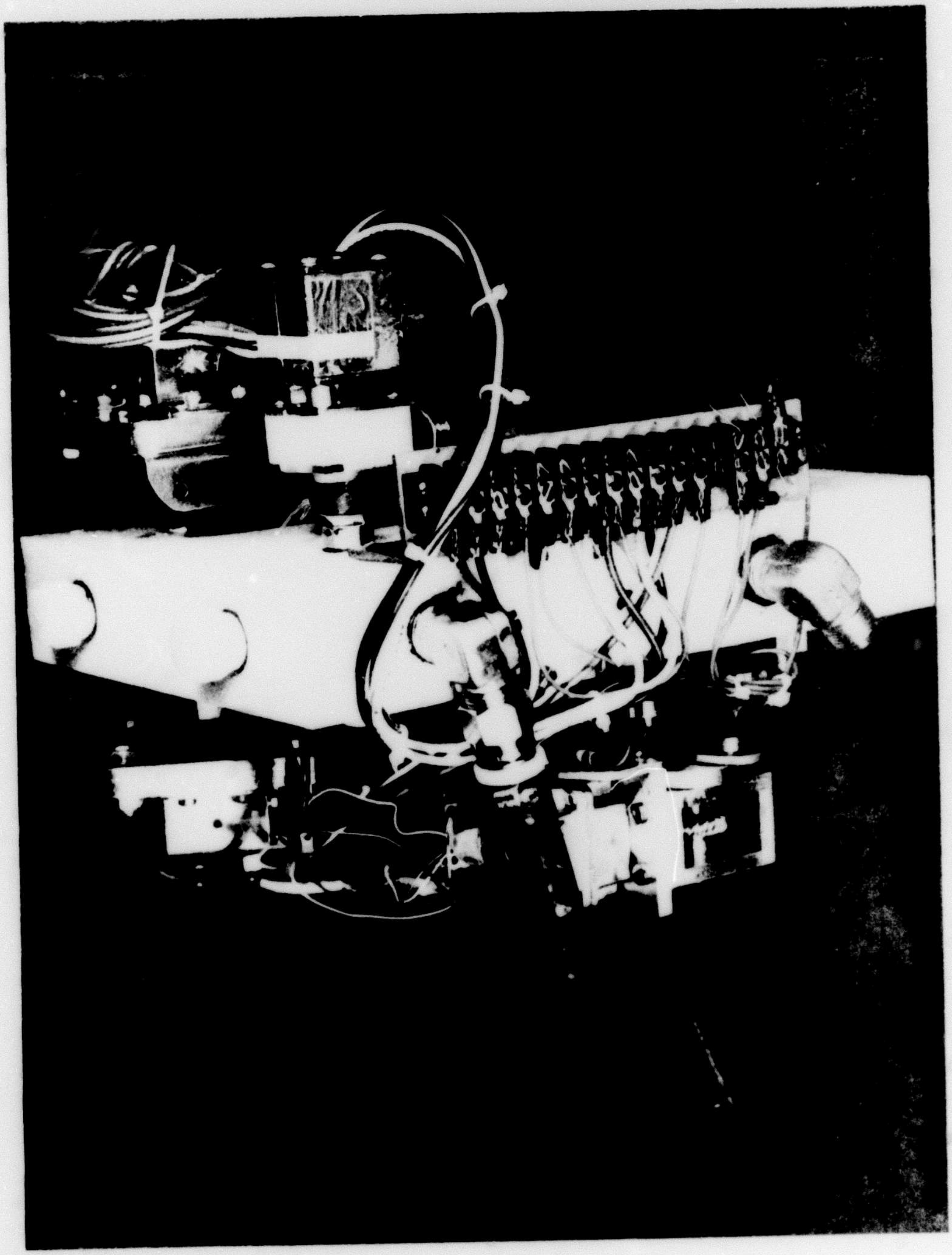

Figure 4. Sea Water Control Manifold Used to Direct the Skid Clamp Actuation Fluid

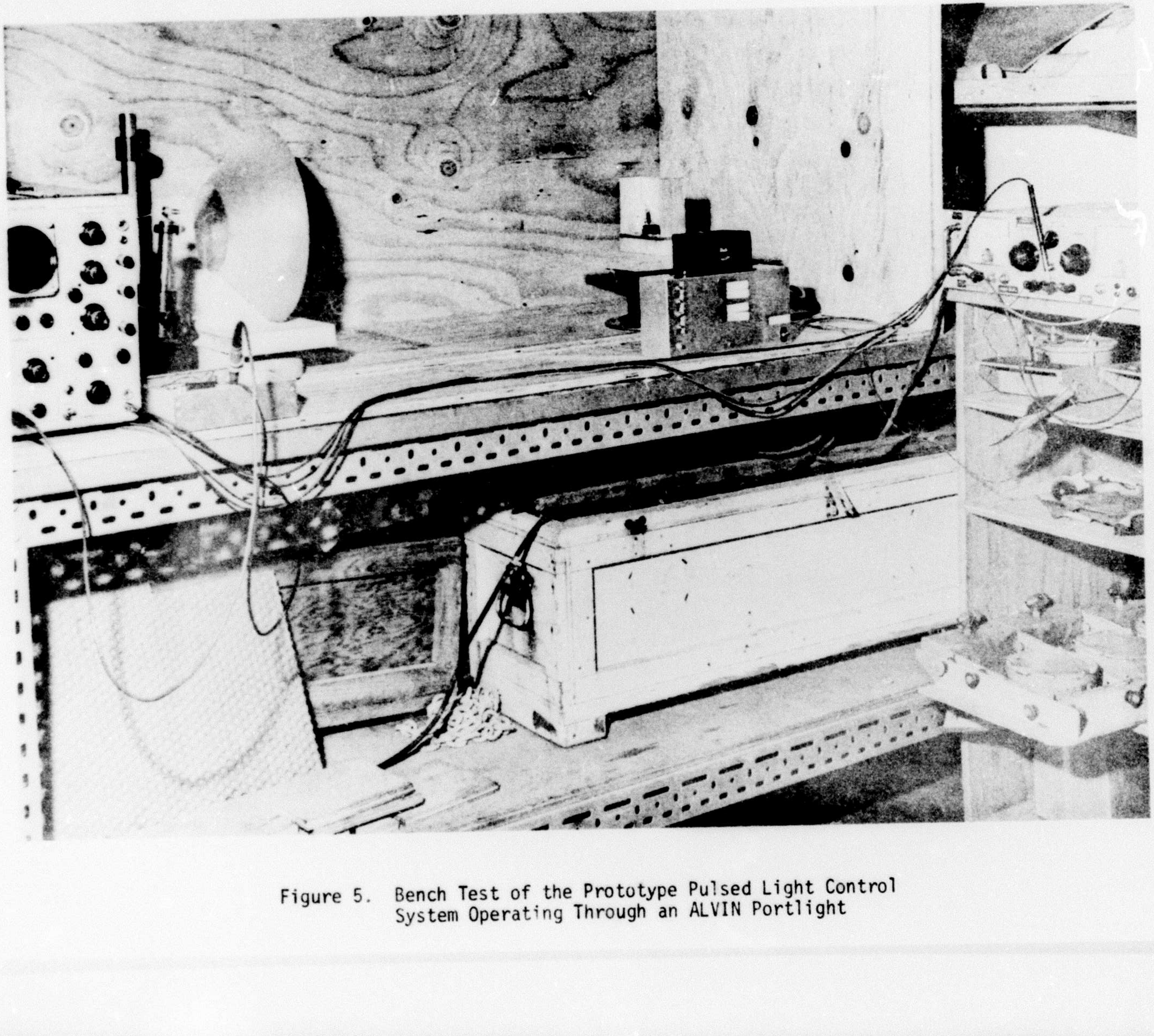

Figure 5. Bench Test of the Prototype Pulsed Light Control System Operating Through an ALVIN Portlight

Modular Acoustic System

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Modular Acoustic System

Our efforts during the second, full six month period under this contract were expended in work on the basic system components, namely Control and Display, Tape Monitor and Log, Transmitters, Trainable Mount, and the Surface and Submersible Computer Systems. Many of these are completed or nearing completion, as discussed below. We anticipate some dockside testing of the complete system during the next six month period.

Control and Display

With the exception of some decoding circuitry for the query displays, the main control chassis is completed. This includes all manual controls for system operation as well as the means for operator communication with the computer when the system is under computer control. All system power supplies are contained in this unit as well as a four ampere-hour, nickel-cadmium battery stack. The power supply system provides all necessary voltages for the various subsystems. All power supplies operate from the submersible's nominal 3C volt main bus. The following voltages/currents are available.

1) plus and minus 14 volts regulated at 1 amp
2) plus 5 volts at 3 amps regulated
3) plus 12 volts at 1.6 amps unregulated
4) plus 15 volts at 1.3 amps regulated
5) minus 12 volts at 1.2 amps regulated
6) plus 28 volts at 6 amps unregulated (battery floated on this supply).

The above power supply system consists of a set of DC-DC converters to obtain isolation from the ungrounded (and ungroundable) ship's power bus. The 28 volt grounded system is primarily to provide power for the NOVA computer which draws approximately 5 amperes normally, with higher peaks (surge capability is supplied by the nickel-cadmium battery). In addition, some 28 volt power is used for relays and fans.

There have been some problems with noise in the storage/display system. It appears that the problems have been resolved and final assembly is underway.

Tape Monitor and Logging

The digital data logger has been constructed and tested as part of the main control chassis. It includes the system clock as well as the scanner circuitry.

The tape recorder has been tested. Manual, local controls which were not part of the original recorder have been built and installed in the tape recorder proper. Mountings have been designed and fabricated allowing the recorder to be pulled out from the panel as a drawer to facilitate tape changing.

The Sonar receiver is incorporated into the chassis unit with the tape recorder. The receiver is basically a broad band low noise amplifier with provision for heterodyning an incoming signal down to a lower frequency or set of frequencies and applying these band-shifted signals to a filter set. The

outputs of the filters can be further processed by the computer.

The receiver itself incorporates tunable high and low-pass filters and accurately calibrated gain stages to allow quantitative analysis of the signal returns. Total gain is variable over a range from zero to 100 db over the frequency range 500 Hz to 50 kHz. The receiver is completed and tested.

Trainable Mount

The trainable mount is almost complete. All major mechanical work is done, including the installation of a hydraulic brake system to prevent drift in elevation setting due to the weight of the transducer. A set of torsion springs has been obtained to enable approximate counter-balancing of a variety of transducer loads. These springs are interchangeable in a few minutes to accomodate different loads.

Solid state motor driving circuitry has been designed and tested for operation at 10^4 psi. The entire electronics package is oil-filled and pressure equalized including the 24 volt, 20 ampere hour battery pack for the mount. Except for final connector installation, the electrical and electronic system is complete.

Transmitters

Both transmitter/battery assemblies have been fabricated and tested. Full 600 watt CW output is available from both units into resistive loads.

A transmit-receive relay package is presently under construction. An attempt was made to eliminate the relay from the system by using electronic switching. It was rejected since broad band noise from the power amplifiers cannot be gated out without powering down the amplifiers. A high speed vacuum T-R relay has been purchased and a housing is being made.

Surface and Submersible Computer Systems

In our prior report we noted the delivery of 1) the surface computer system, made up of a Data General 1220 Nova Computer and peripherals such as disk, high speed reader and the CRT Terminal, and 2) of the submersible computer system, made up of a 1210 Nova computer, whose peripherals will include frequency synthesizer, cassette tape deck, and other items of our own construction. Briefly, this half-year period has been spent in 1) overcoming the problems inherent in any new computer system, 2) writing and testing some initial programs, and 3) designing and constructing more hardware for interfacing components to both surface and submersible systems.

> 1) Problems associated with a new computer system. Since the Nova computer is new to Woods Hole, some time has been expended in training hardware and software personnel in its proper use, a problem which would have been less severe had we been able to use a Hewlett-Packard system. We had to eliminate some system incompatibilities such as the inability of the high speed reader to process certain system programs; we encountered some deficiencies in Data General's disk operating system which we can generally circumvent; and we had

initial difficulties in getting the CRT to function both because of some minor design errors and component failure.

We feel that most of those problems are now behind us, and that we understand those functions and limitations of our computer system which relate to our system development.

2) Programming. Programs were written for two major sections of the system - the frequency synthesizer and the cassette.

The frequency synthesizer is the device which generates a train of single-frequency pulses, which are then power-amplified and sent to the transducer. Two programs have been written and successfully tested using the synthesizer interface developed in the prior half year. The first, IMP, repeatedly outputs a train of three pulses, each of different frequency. The pulse length and frequency is under operator control, as is signal amplitude through an attenuator control. Wave shape is preserved from pulse-to-pulse since each pulse starts at the zero-crossing. In addition, control signals are generated to change the transducer from send to receive after the last pulse and to output a beat frequency which is used in the filter networks.

The second, SEEK, is a preliminary version of the program necessary for running the system as an acoustical spectrometer. It is like IMP with the additional capability of incrementing the frequencies of a train after the train has been transmitted the desired number of times. Since this increment can be selected by the operator, one has the means of stepping through a spectrum.

We should emphasize that program parameters such as pulse length and frequency increment are entered by toggling the computer front panel; however, in the final version, they will be entered by keyboard when that unit has been implemented. A further point is that we envision many other output waveforms such as FM-sweep, which lie within the capabilities of the synthesizer.

The cassette tape deck is the device with which the operator submits various programs to the submersible computer to permit operation of the acoustical package. Two working programs have been written for the cassette. The first, CDLPK, permits the loading of the entire contents of core, the so-called core image, from cassette. In addition, it permits a program which has been developed in the surface system to be dumped onto cassette so that a program can be efficiently transferred from surface to submersible system.

The second program is called CBOOT and is a bootstrap loader for CDLPK. It is a very short program which can be toggled into the submersible computer, thereby enabling the operator to quickly load the much longer cassette loading program. The actual testing of these programs with the Ross cassette tape deck proved successful late in 1973.

Other programming efforts included a refinement of the keyboard/ echo display programs sketched out in the prior half-year. These will permit the entry of program parameters.

3) Hardware Interfacing. The interfacing for the submersible system components is being carried out for the surface system as well, due to the necessity of testing programs in the surface system during development. This is particularly true with the Ross tape deck and the synthesizer. The interfacing we report here has been implemented so far only for the 1220 or surface system.

The interfacing logic for the Ross tape deck has been installed, and the Ross fully exercised by the computer, under program control, testing its mechanical functions and the recording and playing back of blocks of data.

Eight modular circuit boards intended for interfacing in the 1210 computer have been designed and delivered. The wiring of two of these boards has been started. All eight will ultimately interface the following peripherals for the 1210: Rockland synthesizer and associated interrupts, Ross tape deck, keyboard read-in, keyboard query, echo display, Hughes storage tube, transducer pedestal control, analog-to-digital data acquisition module, and filters.

The on-board computer has been converted to operate from 28 V DC rather than AC. It has been operated from the isolated DC power system described in the control section earlier.

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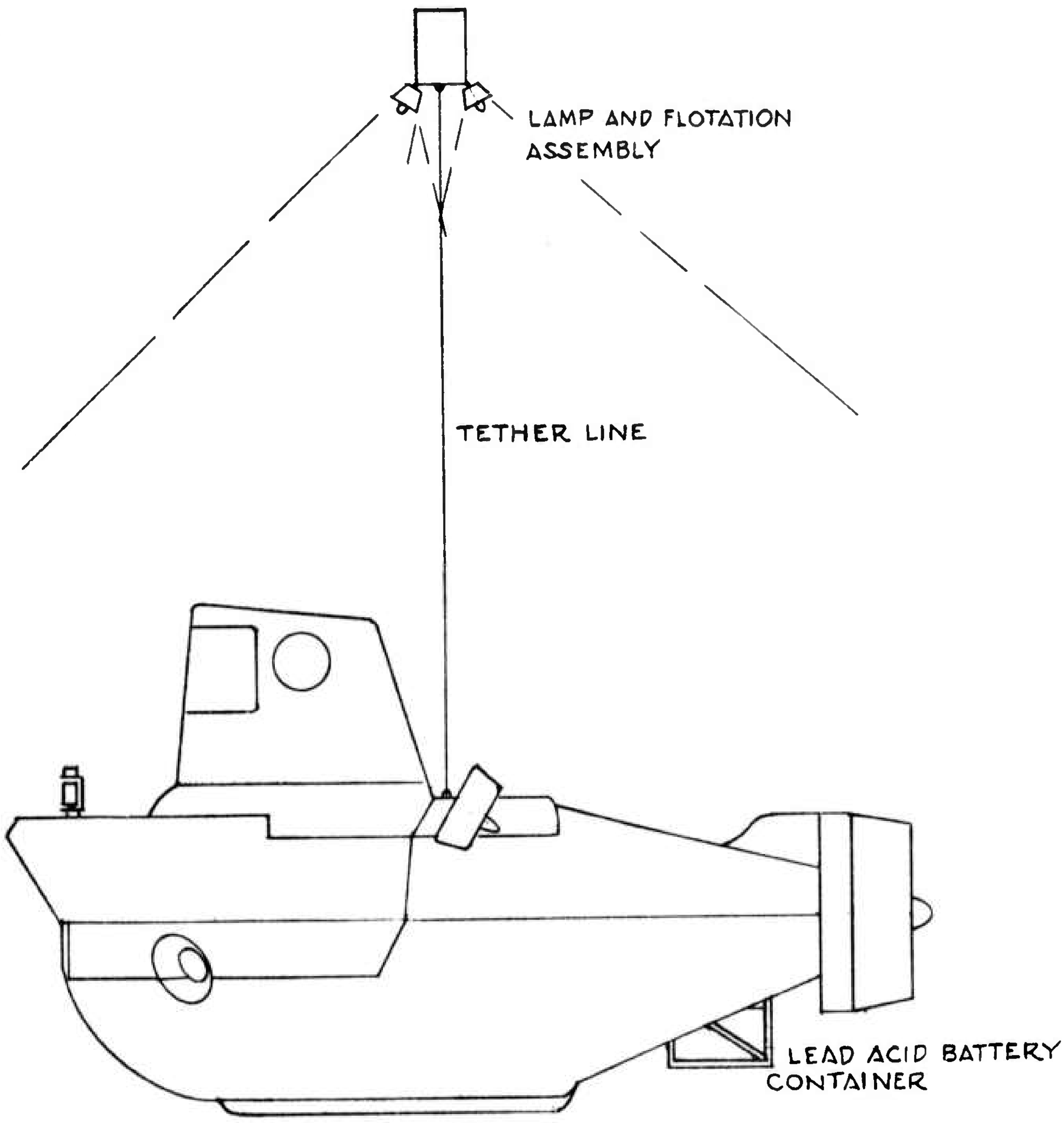
Construction of a tethered lamp and battery power package for use with the ALVIN submersible has begun. Figure 1, illustrates the device under construction. The 30 volt DC lead acid battery system will be mounted below the aft fairing. The mechanical portions of the main box and mounting frame assembly has been completed.

The electrical components; fuses, contactors, overload relays, and their associated wiring are presently in construction. The battery box, as well as the electrical control system will be an oil compensated device to allow operation at all depth the vehicle is capable of reaching. Both the circuitry and voltage output is compatible with the ALVIN submersible system.

The overhead lamp assembly will consist of a syntactic foam float, and two separately controlled lamp assemblies. One lamp will consist of the standard tungsten filament incandescent lamp. The second assembly will consist of a high gas pressure xenon gas arc lamp. Comparison tests will be performed on each lamp to determine their ability to extend the visual observation range of the submersible.



TETHERED INCANDESCENT FLOOD LAMP

Figure 1.